

Introduction to Nonlinear Control
EML 6350
Class Periods: MWF, Period 9 (16:05 – 16:55)
Location: NEB 0201
Academic Term: Fall 2025

Instructor:

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Office Hours: Tuesday and Thursday, 16:05 – 16:55, NEB 555

Course Description

Introduction to nonlinear analysis and control systems theory. Lyapunov-based analysis and design techniques.

Course Objectives

Develop skills and knowledge required to design and analyze controllers for nonlinear dynamical systems. The specific learning outcomes are:

1. Analysis of nonlinear dynamical systems: Brief introduction to nonlinear behavior (multiple equilibria, bifurcations, chaos, etc.), review of useful concepts from real analysis, existence and uniqueness of solutions to nonlinear differential equations, basic Lyapunov theory, invariant set theorems, stability of time-varying systems, practical stability, input-output stability, input-to-state stability, control Lyapunov functions, contraction. If time permits, timescale separation - singular perturbations, absolute stability, and stability of switched and nonsmooth systems. The students will
 - a. develop an understanding of nonlinear phenomena using tools such as MATLAB/Simulink;
 - b. use knowledge from real analysis, physics, differential equations, and linear algebra to analyze the behavior of dynamical systems; and
 - c. formulate and present rigorous mathematical arguments.
2. Design of feedback controllers for complex engineering systems: Control design methods based on each of the analysis methods above will be discussed. In addition, topics such as integrator backstepping, robust control, and adaptive control will be discussed. If time permits, we will cover feedback linearization, observers and filters. The students will
 - a. apply and understand the implications of the concept of feedback control;
 - b. design closed-loop control systems based on feedback of measured signals; and
 - c. learn an array of tools that can be used to design controllers for nonlinear systems.
3. Literature review: The students will also gain the ability to read and understand the literature on nonlinear systems and control.

Required Textbooks and Software

The course assignments will involve computer simulation of nonlinear dynamical systems. The students are free to use MATLAB, Simulink, Python, or Julia. If you decide to use anything other than MATLAB or Simulink, then I may not be able answer code-related questions.

Recommended Materials

- Nonlinear Systems by Hassan Khalil, Third Edition, Prentice Hall, 2002, ISBN: 978-0130673893
- Nonlinear Control by Hassan K. Khalil, Pearson, 2014, ISBN: 978-0133499261
- Introduction to Nonlinear Control: Stability, Control Design, and Estimation by Christopher M. Kellett and Philipp Braun, Princeton University Press, 2023, ISBN: 978-0691240480
- Nonlinear Dynamical Systems and Control: A Lyapunov-Based Approach by Wassim M. Haddad and VijaySekhar Chellaboina, illustrated edition, Princeton University Press, 2008, ISBN: 978-0691133294

Required Computer

Recommended Computer Specifications: <https://it.ufl.edu/get-help/student-computer-recommendations/>

Course Schedule

Week 01 (08/17):	Overview / Lecture notes - Module 1
Week 02 (08/25):	Overview / Lecture notes - Module 1
Week 03 (09/01):	ODEs, existence, uniqueness / Lecture notes - Module 3
Week 04 (09/08):	Stability / Lecture notes - Module 3
Week 05 (09/15):	Lyapunov's method / Lecture notes - Module 4
Week 06 (09/22):	Control design / Lecture notes - Module 4
Week 07 (09/29):	LaSalle invariance / Lecture notes - Module 4
Week 08 (10/06):	Control barrier functions / TBD
Week 09 (10/13):	Computational techniques (SOS) / Lecture notes - Module 5
Week 10 (10/20):	Computational techniques (SOS) / Lecture notes - Module 5
Week 11 (10/27):	Time-varying systems / Lecture notes - Module 7
Week 12 (11/03):	Backstepping / Lecture notes - Module 8
Week 13 (11/10):	Adaptive control / Lecture notes - Module 8
Week 14 (11/17):	Practical stability / Lecture notes - Module 9
Week 15 (12/01):	Input-to-state stability / Lecture notes - Module 9

Important Dates (tentative dates, subject to change)

09/15: Exam 1 (take-home, 1 week)

10/13: Exam 2 (take-home, 1 week)

12/01: Exam 3 (take-home, 2 weeks)

12/03: Class project due

Evaluation of Grades

Homework may be assigned (in-class problems and take-home problems) but will not be graded. Select solutions may be posted on Canvas. If you do not attempt the homework and simulations on your own, then the resulting lack of understanding will be reflected in the exams.

I will continually assess your progress through short quizzes. The dates for the quizzes will not be announced. The quizzes will be open for attempts for 24 hours. Once you start the quiz, you will have a fixed amount of time (varies based on difficulty of the quiz) to complete the quiz. You are encouraged to work with your classmates to answer the quiz questions. The quizzes will test you on the material covered in class and the assigned reading material. There will be at least 10 quizzes, and your three lowest scores will be disregarded. I will not give make-up quizzes unless you miss more than three under exceptional circumstances. I will require you to present written evidence in support of your claim and I will decide if the excuse is legitimate. The first few quizzes may focus on material that was covered in undergraduate control classes. **Make sure that you brush up on topics such as superposition, state-space, stability.**

Assignment	Total Points	Percentage of Final Grade
Exams (3)	100 each	75%
Quizzes (10)	10 each	10%
Class project	100	15%

Grading Policy

I reserve the right to change the demarcations for the letter grades based on the overall performance of the class but they will not be higher than those shown below.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67

86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

Academic Policies & Resources

See <https://go.ufl.edu/syllabuspolicies>.

Commitment to a Positive Learning Environment

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University's core values.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Coordinator
- HWCOE Human Resources, 352-392-0904, student-support-hr@eng.ufl.edu
- Pam Dickrell, Associate Dean of Student Affairs, 352-392-2177, pld@ufl.edu